In-flight Testing of Onboard UHF Equipment

Miles Sue, David Hansen, Ted Peng
NASA/Jet Propulsion Laboratory
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Abstract

This paper proposes a plan to allow future flight projects to accomplish in-flight testing of on-board UHF equipment which the spacecraft carries for local relay link use at planet Mars only. This plan relies on onboard self-testing to verify receiver functional capabilities at various data rates, and on RF testing with narrow band CW signals transmitted at selected frequencies from an Earth station, non-interfering to existing UHF users, to verify the RF performance of antenna and microwave equipment. The Mars mission planners at JPL have accepted this concept as reasonable. The plan will be practical to implement with a frequency agile local link transceiver, like the next generation UHF transceiver being developed at JPL. The user can test it at one frequency and operate it at a different frequency within the operating range. Possible frequencies for uplink testing are identified. Further effort is needed to select specific test frequencies that will be agreeable to the users to which these bands are allocated.

1. INTRODUCTION

Deep-space missions to planet Mars usually carry a UHF relay system for local link communication at the planet. The mission needs to conduct in-flight testing after launch or when it is in orbit after a long period of dormancy. The purpose is to validate proper operations of the local link communication system (such as the transceiver and the RF front end) and to calibrate RF equipment performance (e.g., antenna gain and microwave circuit loss). It is necessary to know the performance of the relay system soon after launch so that there would be time to adjust the mission planning if necessary. Often, an existing mission would also serve as a communication relay to a subsequent mission. Knowing the performance of the relay system on board the existing mission is crucial to planning the subsequent missions.

The need for a mission to conduct such a test is very infrequent: one test in about a month after launch and another test as needed after the spacecraft reaches the planet. A further test may be needed if the onboard UHF radio is not used for many months. Each test would involve only a few (less than 5) uplink sessions, one session per day, spread over a period of a month or less. Each session involves about one hour of transmission.

Up to now an in-flight UHF test is conducted in the following way. An earth station would transmit to the spacecraft a UHF carrier modulated with test data and would receive a UHF downlink modulated with data from the spacecraft. The problem is that such tests can only be conducted on non-interfering basis because UHF frequencies are allocated to other Services on Earth, not to Space Research Service (SRS). UHF downlink signals received on Earth are too weak to interfere with the other Services. But a UHF test signal transmitted from an Earth station with high EIRP could interfere with other Services. In June 2001 Mission Odyssey had to carefully coordinate the bandwidth and minute-to-minute schedule of Earth station transmission with the National Oceanographic and Atmospheric Administration (NOAA) to avoid harmful interference to the GOES satellites in the geo-stationary orbit.

The purpose of this paper is to recommend a plan to permit the Mars missions to conduct limited in-flight UHF testing while minimizing harmful interference to other users.

2. A PLAN FOR CONDUCTING IN-FLIGHT TESTING

The plan contains two parts: use self testing on-board to verify the functionality of the receiver at various data rates, and conduct limited RF testing with CW or narrow band test signals transmitted from an Earth station to verify the RF performance such as dB degradation in the antenna, microwave circuit and the receiver.

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2.1 On-board Self-Testing

The functionality of an on-board receiver is tested by a signal source on board. The source generates date rates and modulations to verify that the receiver can indeed receive and process the signals at these data rates and modulations. RF performance is not an issue here. The Electra transceiver being developed for future Mars local link applications is designed to have such a capability. Annex 1 gives three examples to illustrate the technical feasibility of implementing self-tests.

2.2 Narrow-Band RF Testing Using Signals Transmitted from an Earth Station

It is very difficult to use a signal source on board to calibrate or validate the RF performance of the UHF signal path including the antenna, the microwave components and the receiver front end. The only practical way to calibrate RF performance is to use a test signal transmitted from an earth station. The test signal has to be narrow band, using a CW carrier without modulation, at a frequency agreeable to existing Services to which the frequency is allocated. In case a mission finds it necessary to include a narrow band modulation in the test signal the mission must take extra care to ensure that such inclusion will not cause harmful interference to any other Service.

Since Mars missions are only allowed to transmit UHF from Earth stations on non-interfering basis (NIB), and most of the possible local link frequencies (390-405 MHz and 435-450 MHz) will not be acceptable to existing Services, future missions to Mars should use frequency agile receivers for the local links. Such receivers can be controlled to be tested at one frequency and to operate different frequencies. Frequency agility is already included in the capability of the Electra receiver being developed in NASA for the next generation Mars relay system.

Based on discussions with the Mars mission telecom team at NASA/JPL, a CW uplink test of RF performance coupled with an on-board self-test of receiver data rate capabilities can meet most, if not all, essential objectives of in-flight testing.

3. CANDIDATE UPLINK TEST FREQUENCIES

It is necessary to identify a few candidate frequencies for use in uplink testing that will be non-interfering and therefore acceptable to the existing UHF users. Considerations must be given to the CCSDS recommended UHF proximity link (local link) frequencies, future equipment capabilities and the legitimate users of existing allocations according to applicable regulations.

3.1 CCSDS Recommendations and Capability of Future Transceivers

The CCSDS has recommended the 390-405 MHz subband and the 435-450 MHz subband for proximity links (or local links) in the return and forward directions respectively. The Electra transceiver is designed to operate across these bands with frequency agility. In the full-duplex mode, the transceiver on an orbiter can transmit in any frequency within the forward frequency subband and receive in any frequency within the return frequency subband. If the Electra transceiver is on a landed element, the reverse is true. In the half-duplex mode, the transceiver can either transmit or receive, one at a time, in the entire UHF local link frequency band, 390-405 MHz. Planning to conduct the uplink test in the half-duplex mode will allow greater flexibility in selecting a candidate frequency. The Mars architecture team has indicated that conducting the test in half-duplex mode is sufficient, and that there is no known requirement for testing in the full-duplex mode.

3.2 Allocation and Regulatory Considerations

The UHF spectrum is used for many applications. In the United States, for example, the 335-400 MHz band is allocated to military fixed, mobile and mobile satellite services. The 400-401 MHz band is allocated to standard frequency and time satellite, meteorological aid, and downlink of meteorological satellite, mobile satellite, and space research. The 401-403 MHz band is allocated to the uplinks of meteorological aids and meteorological satellite. The NOAA GOES satellites use this band for uplink. The Mars Global Surveyor and Mars Odyssey missions must seek coordination with NOAA to transmit uplink test signals at 401.6 MHz from Stanford, California. Uplink testing should not use these bands as it may interfere with the satellite services.

The 403-406 MHz is allocated to meteorological aid (radiosonde). Because of the limited altitude of radiosonde it may be possible to coordinate with the radiosonde users locally to avoid interference.

The 406-410 MHz is allocated to fixed, mobile, and radio astronomy services. The 410-420 MHz band is allocated to fixed, mobile and space research (space-to-space). In the United States, the NTIA has also divided the 406-420 MHz in 12.5 kHz channels and allocated them to government agencies, including NASA. NASA has received 15 channels as follows:

Table 1. Land Mobile Channels Allotted to NASA

406.2375 MHz	415.2375 MHz
406.4375	415.4375
406.8375	415.8375
407.0375	416.0375
407.2375	416.2375
407.4375	416.4375
407.6375	416.6375
414.1375 (simplex only)	

The 420-450 MHz band is allocated to military radiolocation. Since the frequency range is wide and the users are government agencies it may be possible to obtain permission to conduct uplink testing with coordination.

4. CONCLUSION

The proposed plan will allow Mars missions to conduct necessary testing of the UHF relay link equipment in flight, with minimum or no harmful interference to the users to which the UHF bands are allocated. Implementing the proposed on-board self-testing will greatly reduce the bandwidth requirement of uplink testing. The frequency-agile next generation transceivers will enable full implementation of this plan.

Considering various Services using the existing allocations, and the possibility of coordination on non-interfering basis, it appears that some viable uplink test frequencies may be found in the 406-417 MHz land-mobile band given in Table 1, the 403-406 MHz radiosonde band, or the 420-450 MHz military radiolocation band. Further work is needed to find the specific frequencies and obtain agreement from the NTIA.

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Annex I
In-flight, Near-Earth Testing of on-board UHF Equipment

Figure 1 shows a candidate self-test scheme being considered by a NASA mission, Deep Impact. Deep Impact employs an S-band link between the spacecraft and the impactor. The self-test plan is however applicable to Mars missions carrying a UHF relay package, providing that elements at both ends of the local link are launched together.

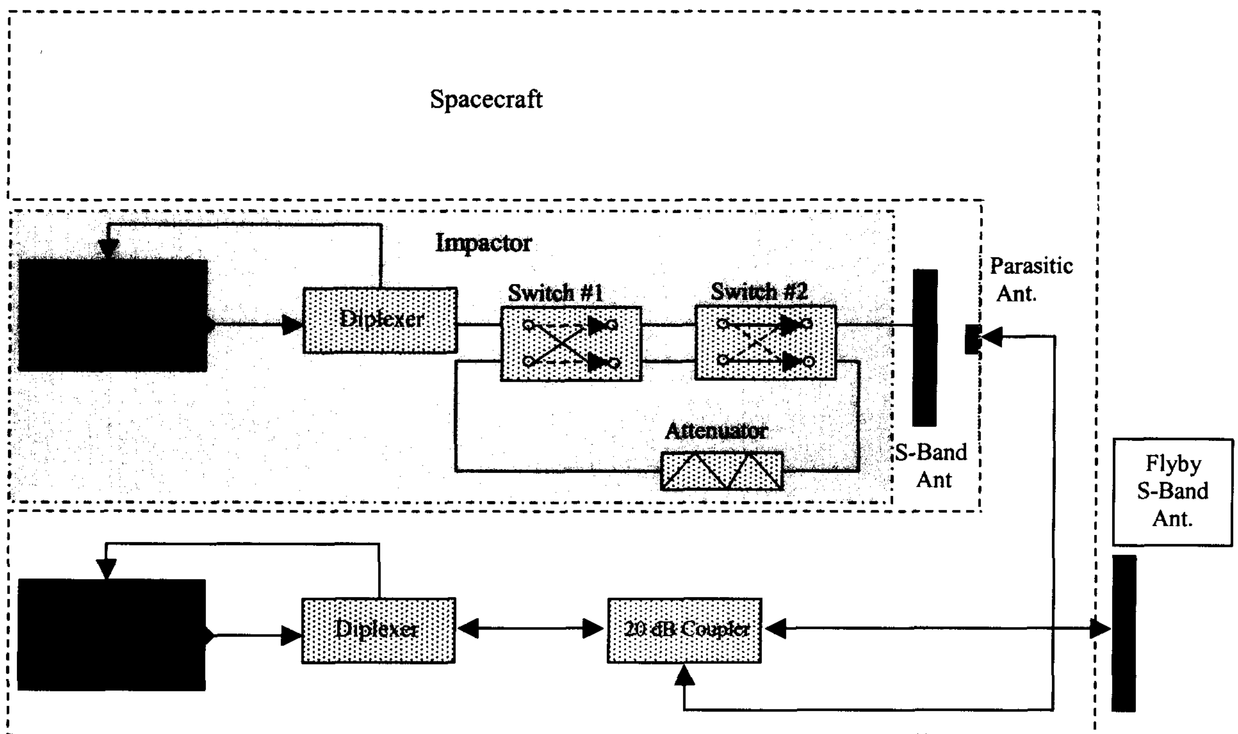

Figure 1. A Candidate Self-test Plan Being Considered for The Deep Impact Mission

If only one element at the two ends of the relay link is launched, a self-test scheme can still be implemented with slight modifications to the telecommunications system. If the spacecraft is flying a dual-string telecom system, the modifications and the resulting impact on the spacecraft are minimal. The block diagram in Figure 2 illustrates the concept, where it has been assumed that the transceivers are frequency-agile (able to operate at different frequencies in a range), such as the Electra transceiver that is being developed by NASA. If the spacecraft is flying a single-string telecom system, the impact is more significant. Figure 3 shows a self-test block diagram for a spacecraft having only a single-string telecom system. It has been assumed that in this case the spacecraft will carry a second transceiver for test only. The test transceiver will have reverse frequency channels as the regular one.

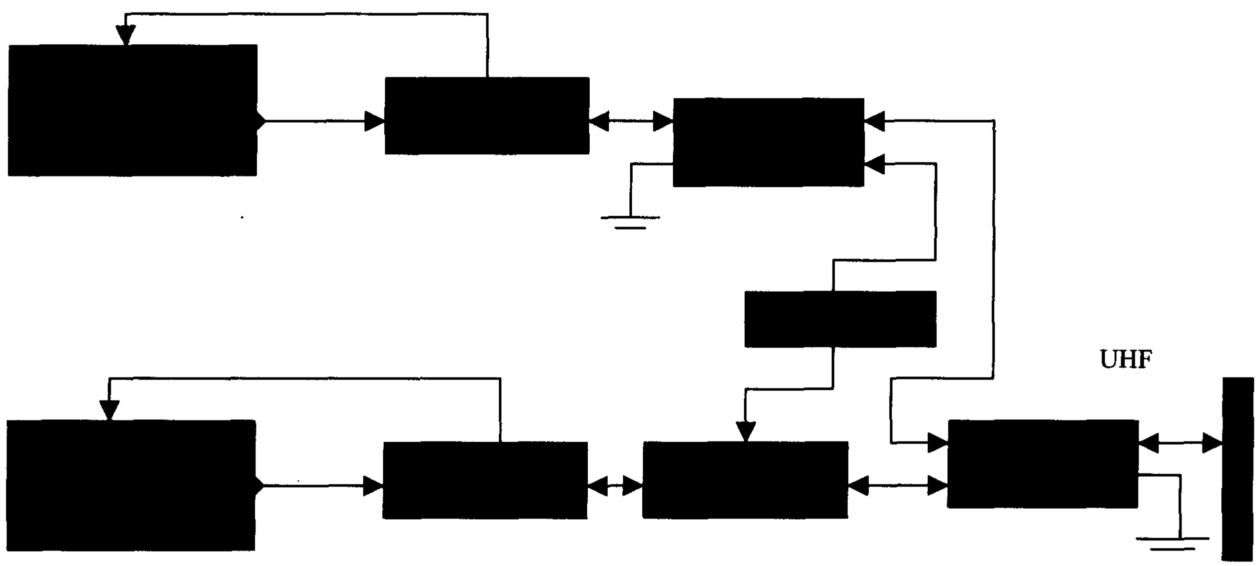

Figure 2. UHF In-Flight Test Block Diagram for a Dual-String Telecom System
(assuming that the transceiver is frequency agile and can receive and transmit in both sub-bands.)

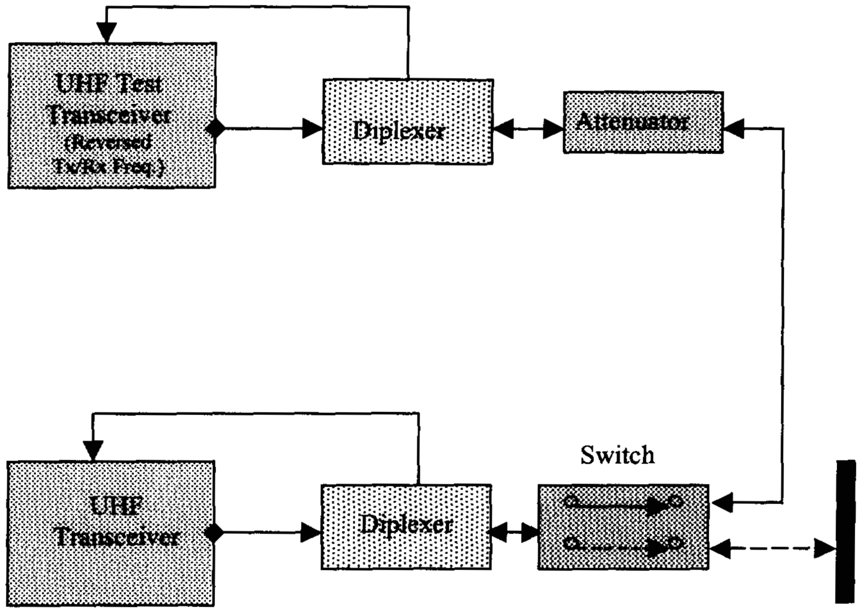

Figure 3. UHF In-Flight Test Block Diagram for a Single-String Telecom System
(assuming that the spacecraft carries a 2nd UHF transceiver for testing.)